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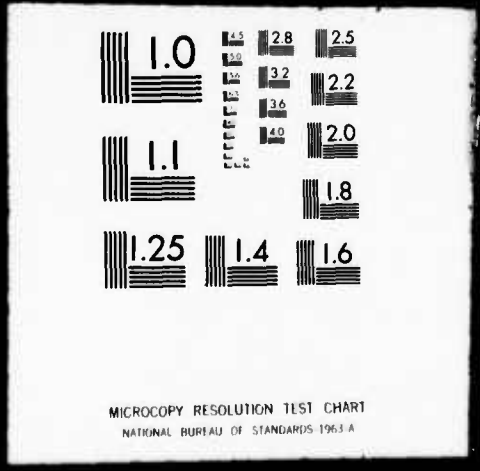

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OPERATIONS RESEARCH CENTER

Massachusetts Institute of Technology

Cambridge, Massachusetts 02139

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July 1, 1977 through June 30, 1978

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I. INTRODUCTION

The Operations Research Center conducts interdepartmental academic and research programs in the field of operations research. The academic staff of the Center is drawn from many departments, including the Sloan School of Management, Electrical Engineering and Computer Science, Urban Studies and Planning, Aeronautics and Astronautics, Civil Engineering, Mathematics and Physics. At present, approximately 18 students are in the operations research doctoral program and a comparable number are in the master's program. Most of them come to M.I.T. specifically to study operations research and are admitted directly by the Center, although some learn about the graduate operations research program by attending seminars or subjects.

During the past year, the academic staff of the Center have engaged in a wide range of research activities sponsored directly by the Center. Several of these endeavors represent major new research directions for the Center. These include new work on urban transportation planning (using network analysis), the role of operations research in public program evaluation, the development and use of large scale mathematical programming models for energy resources planning, and modeling of processes yielding data on crime frequencies. Many of these new efforts, as well as several of the on-going efforts, have required significant new work in the theory and methodology of operations research.

One focus of basic research has been on nondifferentiable optimization. This has been motivated in large part from the Center's work on econometric models containing linear programming subproblems. Linear programs produce nondifferentiable parametric functions because of the abrupt changes in shadow prices as various optimal extreme point solutions are generated. Specifically, normative models for depletable resources with applications to energy planning have been developed and analyzed. Nondifferentiable optimization techniques are required, for example, to estimate derived demand curves for a scarce resource from a dynamic economic sectoral model. Another example is the use of nondifferentiable optimization to compute peak load electricity prices by perturbing peak load demand and reliability constraints in utility capacity expansion models.

A related project with the Brookhaven Energy System Optimization Model (BESOM) was originally funded to study the incorporation of nonlinear supply functions into it. Sensitivity analyses were performed on the Brookhaven model and it was found that the model definitely requires nonlinear supply functions to smooth out derived demand for primary supplies. This work led to the development of a large scale mathematical programming regional model of coal supply in the U.S. The coal supply modeling is still underway. In addition, O.R. staff and students abstracted the features of the Brookhaven model to construct a dynamic U.S. energy sector model for use in their work on depletable resources. The first version of that model is now complete.

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Continuing experimental work in integer programming dual methods has produced a large scale, interactive mixed integer programming code which combines state-of-the-art branch and bound methods with the dual methods. Current experimentation with these methods is under way to try to understand the correct balance to be taken between the various complementary methods. The theoretical work has been focused on methods of multicriterion mixed integer programming, and a new approach to these problems called inverse optimization. Inverse optimization involves the use of Lagrangean duality to quickly generate collections of solutions that are optimal in a family of related problems.

Finally, basic research has continued on the integration of numerical optimization methods with computational schemes for solving nonlinear robust regression problems. A key element in the numerical calculations has been the development of quasi-Newton or update methods for approximating the appropriate Jacobean matrices. The ultimate goal of this research is the development of modular computer systems for a wide variety of statistical problems.

During the past year, there were several research projects focusing O.R. methods on public sector problems. The Center's commitment in this area is illustrated, for instance, by a new two-week summer course it is offering for the first time, "Recent Advances in Public Sector Operations Research" (highlighting work in energy planning, transportation, urban systems, health and criminal justice).

Our on-going studies of public attitudes and behavior with regard to blood donation are near completion, with the fifth and last technical report to be published in the summer of 1978. Some simple indications of the findings are (1) about half of the people presently eligible to donate blood have made at least one donation, (2) donors and eligible nondonors do not differ significantly in their perceptions of the need for blood, (3) even many frequent donors have no occasion to develop consistent positions with regard to blood collection ideology, and (4) the primary reason "so few" people give blood each year is that their contributions provide for an adequate whole blood supply. Extensive documentation is provided by the Center's project reports.

Another public sector project, which was completed this year, focused on evaluating the consumer's interest in merit rating plans for automobile insurance. Auto insurance premiums for individual insureds often depend upon the insured's own claims' experience and traffic violation record during previous years. The surcharge and credit schedules used to adjust premiums up or down based on the number of past incidents are called "merit rating" plans. This research project used probabilistic models for claims' experience to compare the cost redistribution effects of alternative merit rating plans being considered for use in Massachusetts and to recommend practical designs that treat insureds equitably. The

design now being implemented in Massachusetts differs from those customarily used in other states in accordance with some of the project's recommendations.

A major new effort was launched this Winter to evaluate program evaluations in criminal justice. Center staff and students are now selecting two samples of criminal justice evaluation - one from "logistical" programs (such as police patrol) and the other from strictly social service programs. Each sample is to be evaluated as to approach and content, with particular emphasis on current and potential roles of decision analysis and mathematical modeling in evaluation studies. In evaluation methodology, it is planned to review currently popular evaluation methodologies and to assess the applicability of each to in-the-field criminal justice evaluations. It is then planned to begin to carry out the needed methodological research in order to start to bridge the gap between current theory and practice.

A related area of research, started this Spring, aims to develop statistical methods that better illuminate the implications of crime statistics, both with respect to the magnitude of the problem and to the effects of public policy decisions related to crime. Initially, the work will focus on homicide data, widely believed to be the most accurate crime statistics. Investigations under way now concern the reasons for the drop in the U.S. murder rate in the mid-1970's and the indications of past data about the deterrent effect of capital punishment.

Modeling and analysis of urban vehicular services continued during the past year. It was shown that a classic deterministic location theory problem - the "p-median" problem - can be extended to a probabilistic framework in which facilities to be located (e.g., ambulances) can be busy or available for dispatch according to probabilities computed by the Center's hypercube queueing model. This has led to new work in location theory, optimal dispatch of emergency vehicles, and real-time relocation of emergency vehicles. Additional work in the area of urban vehicular services included (1) the development of an algorithm to determine the shortest rectilinear distance between two points in the presence of barriers of travel; (2) models predicting how buses "clump" together when traveling along a bus route; (3) an evaluation of deliberately delaying subway trains at certain stops to facilitate rapid transfers of passengers between trains. Much of the work on urban vehicular services assumed the existence of a new urban technology: automatic vehicle location systems. Knowledge of the real-time location of vehicles, to a specified degree of resolution, allows more effective system control strategies to be implemented.

Motivated by both practical and theoretical concerns, research continued in the area of transportation network analysis and decomposition techniques. This ongoing project, which has involved the application of

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mathematical optimization modeling and solution techniques to transportation planning, has concentrated this year on rail freight management and urban traffic equilibria. Results in these two problem areas have been a taxonomy of planning issues in rail management, the formulation of a mixed integer programming routing/blocking model to support decision making for rail applications, an existence proof for an equilibrium to a general traffic flow model, and a new algorithm to solve for equilibria for this general model.

A long-term project on multi-level logistics systems received continued support and attention. Decomposition methods were devised and tested to partition, link, aggregate and disaggregate large scale production, inventory and distribution systems. Applications were made to several industrial production planning problems.

Operations Research Center staff and students were also involved in a variety of research activities with other departments and centers within M.I.T. Two students participated in a water resource planning project for Egypt being performed by the Civil Engineering Department. O.R.C. staff and students were involved in projects at the Energy Laboratory on oil exploration and potential uses of geothermal power. O.R. models for airport runways were constructed and analyzed by O.R.C. staff and students, working on a Flight Transportation Laboratory project. Finally, members of the O.R.C. staff were active in research programs at the newly created Computer Research Center for Economics and Management Science. Their activities included the further development of methods of robust regression in statistics and modeling languages for mathematical programming.

Richard C. Larson
Jeremy F. Shapiro

Co-Directors

II. RESEARCH ACTIVITIES

1. Mathematical Methods

1.1 Mathematical Programming and Optimal Control

Staff Reports

G.R. BITRAN, Linear Multiple Objective Programs with Zero-One Variables, Mathematical Programming, 13, 1977, pp. 121-139.

Theoretical results are developed for zero-one linear multiple objective programs. Initially a simpler program, having as a feasible set the vertices of the unit hypercube, is studied. For the main problem an algorithm, computational experience, parametric analysis and indifference sets are presented. The mixed integer version of the main problem is briefly discussed.

G.R. BITRAN, Theory and Algorithms for Linear Multiple Objective Programs with Zero-One Variables, M.I.T. Operations Research Center Technical Report No. 150, May 1978.

A new algorithm and theoretical results are presented for linear multiple objective programs with zero-one variables. A procedure to identify strong and weak efficient points as well as an extension of the main problem are analyzed. Extensive computational results are given and several topics for further research are discussed.

G.R. BITRAN and T.L. MAGNANTI, The Structure of Admissible Points with Respect to Cone Dominance, M.I.T. Operations Research Center Working Paper OR 074-78, April 1978.

The set of admissible (pareto-optimal) points of a closed convex set X when preferences are described by a convex, but not necessarily closed, cone are studied. Assuming that the preference cone is strictly supported and making mild assumptions about the recession directions of X,

(i) a representation theorem of Arrow, Barankin and Blackwell is extended by showing that all admissible points are either limit points of certain "strictly admissible" alternatives or translations of such limit points by rays in the closure of the preference cone, and

(ii) it is shown that the set of strictly admissible points is connected, as is the full set of admissible points.

Relaxing the convexity assumption imposed upon X, the local properties of admissible points in terms of Kuhn-Tucker type characterizations

are considered. Necessary and sufficient conditions for an element of X to be a Kuhn-Tucker point are specified, conditions which, in addition, provide local characterizations of strictly admissible points.

A.R. ODONI, Locations of Medians on Stochastic Networks, (with P.B. Mirchandani), M.I.T. Operations Research Center Working Paper OR 065-77, October 1977.

The definition of network medians is extended to the case where travel times on network links are random variables with known discrete probability distributions. Under a particular set of assumptions, it is shown that the well-known theorems of Hakimi and Levy can be extended to such stochastic networks. The concepts are further extended to the case of stochastic oriented networks. A particular set of applications as well as formulations of the problem for solution using mathematical programming techniques are also discussed briefly.

S.K. MITTER, Quantum Detection and Estimation Theory, (with S.K. Young), Proceedings of the Fifteenth Annual Allerton Conference on Communication, Control, and Computing, September 1977, pp. 62-67.

This paper announces some results on the M-any quantum detection problem.

In the classical formulation of detection theory (Bayesian hypothesis testing) it is desired to decide which of n possible hypotheses $H_1,\ldots,H_n$ is true, based on observation of a random variable whose probability distribution depends on the several hypotheses. The decision entails certain costs that depend on which hypothesis is selected and which hypothesis corresponds to the true state of the system. A decision procedure or strategy prescribes which hypothesis is to be chosen for each possible outcome of the observed data; in general, it may be necessary to use a randomized strategy which specifies the probabilities with which each hypothesis should be chosen as a function of the observed data. The detection problem is to determine an optimal decision strategy.

In the quantum formulation of the detection problem, each hypothesis H_j corresponds to a possible state ρ_j of the quantum system under consideration. Unlike the classical situation, however, it is not possible to measure all relevant variables associated with the state of the system and to specify meaningful probability distributions for the resulting values. For the quantum detection problem it is necessary to specify not only the procedure for processing the experimental data, but also what data to measure in the first place. Hence the quantum detection problem involves determining the entire measurement process, or, in mathematical terms, determining the probability operator measure corresponding to the measurement process.

J.F. SHAPIRO, Sensitivity Analysis in Integer Programming, Annals of Discrete Mathematics 1: Studies in Integer Programming, North Holland Publishing Company, 1977, pp. 467-477.

This paper uses an IP duality theory recently developed by the author and others to derive sensitivity analysis tests for IP problems. Results are obtained for cost, right hand side and matrix coefficient variation.

Student Reports

W.B. SHEPARDSON, A Lagrangean Relaxation Algorithm for the Two Duty Period Scheduling Problem, PhD in OR Thesis, June 1978. Also, M.I.T. Operations Research Center Technical Report No. 152, June 1978.

An algorithm is presented for the two duty period scheduling problem. This integer programming problem has a binary constraint matrix with two sets of consecutive ones in each column. At each subproblem of a branch and bound procedure, subgradient optimization is used to maximize the value of a Lagrangean relaxation, which is a network flow problem. The algorithm is implemented for the two duty period set partitioning problem, with shortest path relaxations. A second algorithm utilizing the unique properties of prime numbers is developed for solving small subproblems. Computational results are reported for several large problems.

1.2 Decision Analysis, Statistics and Stochastic Systems

Staff Reports

A.I. BARNETT and D.J. KLEITMAN, Some Optimization Problems with Bulk-Service Queues, Studies in Applied Mathematics, 58, Elsevier North-Holland, 1978, pp. 277-290.

An optimal control problem for a single bulk-service queue is considered. Theorems that characterize the optimal control strategy in some circumstances are proved; they complement earlier results by Deb and Serfozo for a comparable problem. Most of the analysis uses direct probabilistic reasoning rather than specialized methods such as dynamic programming. Some illustrative examples are presented.

RESEARCH ACTIVITIES: Mathematical Methods

R.C. LARSON, Structural System Models for Locational Decisions: An Example Using the Hypercube Queueing Model, M.I.T. Operations Research Center Technical Report No. 145, March 1978.

A structural system model of a spatially distributed system embodies system dynamics as well as statics, explicitly depicts the various states of system operation, and includes probabilistic as well as deterministic features of operation. In this context, a locational decision is an allocation of resources within an operating system. This paper uses the recently developed hypercube queueing model to illustrate the ways in which locational decisions - both long-term and short-term - can be made within the framework of a system model. Particularly important is state-dependent interaction among facilities (mobile servers) that precludes application of many traditional locational theories. Recent work outlined in the paper includes a generalization of the N-median problem to congested facilities, optimal dispatching of facilities, districting (sectoring), consideration of quality of locational information, and short-term repositioning of facilities. Recent implementations of the model are also discussed.

P.M. MORSE, Solution of the Retiring Search Problem, M.I.T. Operations Research Center Working Paper OR 070-77, December 1977.

The well-known variational principle of the optimal distribution of search effort is applied to the case where the sought-for target has been located momentarily but the search cannot begin until a time T_o later, during which interval the target may or may not move. The optimal search path, called the retiring search curve, is a spiral starting at the point of original location, with the relationship between r and θ or L, the length of path, given by a differential equation derived from the variational principle. This equation is solved for a range of values of the parameters of greatest practical interest. The results are tabulated and also displayed in graphical form for use in practice. General conclusions emerge, of considerable practical value in searches of this kind.

P.M. MORSE, Exact Solution of the Bradford Distribution and its Use in Modelling Informational Data, (with F.F. Leimkuhler), M.I.T. Operations Research Center Working Paper OR 068-77, November 1977.

The Bradford distribution requires a logarithmic relationship between the cumulative distribution F_n, the fraction of items (periodicals, books, information banks, et al.) having "productivity" (number of articles on or references to a given subject, rate of use of the item, et al.) n or more, and the total cumulative "production" G_n of these items. An exact solution is obtained for this distribution for all integer values of $n \geq 1$. The result is compared with the Zipf and the

modified geometric distributions, also of use in describing library and other information data. Examples are given of the operational value of representing informational data by one of these distributions. Simple tests are developed to see how well a given sample of data conforms to one or the other distribution, and are applied to two samples; first the number of OR articles appearing in various journals in a given time interval and, second the rate of use of various physics periodicals in a science library. It is shown that the first fits the Bradford distribution quite well, whereas the second fits the modified geometrical distribution. There is a discussion of some of the implications of this difference.

R.E. WELSCH, Stepwise Multiple Comparison Procedures, Journal of the American Statistical Association, 72, September 1977, pp. 566-575.

This article proposes two new stepwise multiple comparison significance tests which control the experimentwise type I error rate and compares these tests with some existing procedures. The new (step-up) tests begin by examining the gaps between adjacent ordered sample means, then the three stretches, etc., until the range is reached. This reverses a procedure (step-down) proposed by Ryan (1960). Tables for the new tests were constructed using improved Monte Carlo techniques. A simulation study showed that one of the new step-up tests and a modification of the Ryan procedure provided significantly greater power than the commonly used Tukey honestly significant difference test.

R.E. WELSCH, Nonlinear Statistical Data Analysis, Proceedings of the Computer Science and Statistics: Tenth Symposium on the Interface, National Bureau of Standards, February 1978, pp. 77-86.

This paper discusses how recent progress in nonlinear optimization methods can help data analysts working with nonlinear models and nonlinear estimation procedures. Some advances in estimation for linear models such as robust methods and diagnostic sensitivity analysis have been partially generalized to nonlinear models, but many problems remain. These problem areas are discussed along with certain ways in which nonlinear optimization algorithms could be modified to help the statistician.

R.E. WELSCH, Finding Influential Subsets of Data in Regression Models, (with S.C. Peters), Proceedings of the Computer Science and Statistics: Eleventh Symposium on the Interface, North Carolina State University, 1978, pp. 240-244.

This paper discusses a variety of techniques for identifying influential subsets of data in estimated regression models. Single and multiple row methods using deletion and infinitesimal perturbations are treated. The primary emphasis is on the algorithmic issues arising in the computation of these diagnostic measures.

RESEARCH ACTIVITIES: Mathematical Methods

Student Reports

O. BERMAN, Dynamic Positioning of Mobile Servers on Networks, PhD in OR Thesis, February 1978. Also, M.I.T. Operations Research Center Technical Report No. 144, January 1978.

This paper deals with methods to improve the performance of urban emergency systems (police, fire, ambulances,...). The analysis has been performed on a network model of the urban environment, under the assumption that demands (incidents) are generated on the nodes of the network. Starting points for the analysis were the p-median problem for optimum locations on networks, the hypercube spatially distributed queueing Model and recent work on stochastic networks.

Two main stochastic characteristics of urban emergency systems have been taken into account in the analysis. The first one is the stochastic nature of both the demands for service and the service times. This has an immediate consequence on the availability of servers at the times that incidents occur. The second characteristic is the uncertainty regarding travel times on the links of the network. The specific problems analyzed are: (i) where to locate facilities in a congested network with probabilistic demands and service times; (ii) how to improve the operational performance of the system via repositioning policies under various sets of conditions; (iii) how to locate and relocate facilities in stochastic networks (networks with probabilistic travel times).

The median problem has been modified to take into account the possibility that facilities can run out of servers. Here the "state" of the system is defined according to the status of the service units (busy or available). The objective in this modified median problem is to minimize the expected travel time to a random incident weighted appropriately by the equilibrium state probabilities of the system. Under two conditions it has been shown that at least one set of optimum locations exists solely on the nodes of the network. This analysis ties together previously disparate research effort on network analysis and on spatial queueing analysis. Illustrative applications are also included.

The repositioning of urban emergency vehicles is next examined, using the methodology of Markovian decision processes. In practice, urban emergency vehicles (e.g., fire engines) are constantly subject to repositioning in order to assure a proper posture for responding quickly to future demands. The analysis assumes that there are Q servers on the network, located initially at Q nodes - "The Home Locations." Depending on the status of the other server locations, a particular idle server can be moved to any other location of the network. The states of the system are defined according to the status of each location

(occupied or vacant). The policy space consists of decisions on where and when to move servers for any possible state. Various types of policy environments are investigated (e.g., distinguishable vs. indistinguishable servers, repositioning constrained to specific sets of nodes, etc.). The objective in these models is to minimize the long term expected cost of operating the system. Costs reflect response time to incidents as well as the inconvenience and expenses resulting from repositioning vehicles.

Another important part of the paper deals with location and relocation of facilities in a stochastic network. A stochastic network is a network where the travel times between any two points of the network are random variables. The intent here is to model the fact that travel times depend on many unpredictable factors, such as traffic patterns, weather and travel conditions, etc. The network is modeled as changing from one state to another dynamically as a Markov process. Each state differs from all the others by at least one link having a different travel time. The objective is to use this stochastic property and to move facilities to "better locations" as the state of the system changes. The model turns out to be a combination of a search for optimum locations and of an optimum transportation assignment problem. One of the main results of the analysis is that a set of optimum locations exists on the nodes. Solution procedures for the problem are also included.

W.G. GOLUSH, Probabilistic Models for Optimal Seismic Design, SM in OR Thesis, February 1978.

Several probabilistic decision models for seismic design of individual buildings are analyzed. The same models are used for optimal seismic zoning in different regions of the United States.

Results indicate that the optimal design is strongly influenced by the possibility of non-physical losses (such as injury and life loss) which are likely to occur when the building is near collapse. When non-physical risk is small with respect to material losses the optimal design is insensitive to the assumed maximum possible site intensity. In a Markov model of damage accumulation the optimal design is sensitive to the repair strategy. Typically, total repair after each damaging event maximizes the expected benefits.

B.W. LAMAR, What the Textbooks Say about the Design of Experiments, M.I.T. Operations Research Center Working Paper OR 073-78, March 1978.

This report reviews classical experimental designs including single and multiple factor analysis of variance, analysis of covariance, and Latin squares designs. Assumptions used in the models are presented, and tests for violations of the assumptions are described. Examples illustrating primary designs and remarks discussing further model extensions and considerations are also included.

RESEARCH ACTIVITIES

2. Models and Applications

2.1 Urban and Other Public Systems

Staff Reports

J. FERREIRA, JR., Selecting Subsidy Strategies for Housing Allowance Programs, (with D.W. Carlton), Journal of Urban Economics, 4, July 1977, pp. 221-247.

The market effects of alternative housing payment formulas are analyzed and compared for a metropolitan housing market using measures of efficiency and distributional equity. The effects of "earmarking" allowance payments are considered. Estimated market effects are based on a model of housing market behavior over a 10-year period. The results differ significantly from what one might anticipate based on demand analyses of individual behavior. "Housing gap" formulas perform better than percent-of-rent formulas. Certain characteristics of the housing market together with particular income redistribution effects of the allowances appear to explain the market behavior.

C.S. GOODRICH and A.W. DRAKE, Comments about Blood Donation: Nondonor, Exdonor, and Recent Donor Responses to Some Open-Ended Questions, M.I.T. Operations Research Center Technical Report No. 136, October 1977.

This report presents tables of comments made in response to some open-ended questions during survey research activities concerned with public attitudes and decision processes with regard to blood donation. The tables are organized by subpopulations and issues. Subpopulations include groups of respondents such as high school donors, high school nondonors, nondonors in a particularly intense blood collection environment, nondonors in the general public, particularly active donors, etc. Issues include reasons for nondonation and donation, effects of the most recent donation on willingness to give in the future, recent changes in blood donation attitude or convenience, etc.

To provide context for the tables of comments, a limited amount of explanatory material is also included. This report is not, however, concerned with the quantitative analysis of survey results. The primary purpose of this publication is to assist in the orientation of people who are responsible for the recruitment and retention of potential donors.

RESEARCH ACTIVITIES: Models and Applications

R.C. LARSON, Evaluating Dispatching Consequences of Automatic Vehicle Location in Emergency Services, (with E.A. Franck), Computers and Operations Research, 5, 1978, pp. 11-30.

Automatic vehicle location (AVL) systems present to the dispatcher of emergency response units (e.g., police cars, ambulances) the estimated real time locations of units within his service area. Building on a recently developed hypercube queuing model, this paper presents a Markov process model for computing the operating characteristics of the radio-dispatched fleet operating under a policy that dispatches the closest available unit to each call for service (implying use of a perfect resolution AVL system). The model accommodates a realistic description of the service area and rather general spatial deployment policies for units.

In implementing the model for efficient computer execution, the focus is on computation and storage minimizing procedures for generating the state-to-state Markov transition rates. One useful technique involves the effective application of a recently developed backward regenerative unit-step tour of the hypercube. The algorithmic procedures generalize to computer solutions of M/M/N queuing systems with distinguishable servers, different customer classes, and a cost structure for assigning servers (who may be in one of several "postures") to customers of each class.

The paper concludes with a realistic nine-unit police example that indicates the general ways in which AVL dispatching improves (and degrades) system performance.

R.C. LARSON, Police Service Aides: Paraprofessionals for Police, (with J.M. Tien), Journal of Criminal Justice, 6, 1978, pp. 117-131.

Increased professionalization of U.S. police patrol forces has yielded not only higher salaries but, through heightened citizen expectations, greater pressures to provide both more crime-fighting and more call-for-service answering activities. Service calls in particular, requiring diversified skills, have added to patrol workloads. Coming at a time of severe budget constraints, alternatives must be identified and evaluated that focus police skills on police matters and provide for non-law-enforcement services in other ways. Recent experience on one promising alternative resource-police service aides-is summarized here. These paraprofessionals are unarmed but uniformed civilians in marked vehicles who perform non-crime-related activities traditionally assigned to sworn officers. Included is an analysis of their effectiveness in freeing time for sworn officers to pursue crime-fighting activities; their capacity to perform different duties; and their impact on and acceptance by the sworn officers and the community. As in other professions, the introduction of police paraprofessionals will have a major impact on urban services in general and on policing in particular.

RESEARCH ACTIVITIES: Models and Applications

A.R. ODONI, Recent Employment and Expenditure Trends in City Police Departments in the United States, Journal of Criminal Justice, 5, August 1977, pp. 119-147.

Trends in employment and expenditures in thirty-three major city police departments in the United States are separated into two groups and examined for the years 1959 through 1973. Among the items considered are: the size of the growth in city expenditures for the police on an absolute basis and in relation to expenditures for the provision of other services; changes in expenditures for salaries and wages and for the various types of fringe benefits; salary and wage increases for sworn police employees and for supervisory personnel, in inflated and in constant prices; and changes in the size and composition of police work forces: A number of interesting patterns emerge from this analysis and offer the basis for some inferences on possible future disputes and conflicts in this area.

T.R. WILLEMAIN, Bayesian Analysis of Crime Rate Changes in Before-and-After Experiments, M.I.T. Operations Research Center Working Paper OR 075-78, June 1978.

Bayesian analyses are developed for data consisting of counts of crimes before and after the introduction of an experimental crime control program. It is argued that Bayesian analysis is superior to conventional significance testing in that the entire probability distribution of the estimated change in crime rate can be displayed. Furthermore, the new Bayesian methods developed here are more appropriate than available Bayesian approaches to changes in time series because they make explicit use of the discreteness of the crime count data. The analysis assumes that crimes occur in the before-and-after periods according to homogeneous Poisson processes with possibly differing rates. This assumption is verified for the case of the Nashville, Tennessee experiment in saturation levels of police patrol. Application of the new Bayesian methods is illustrated by a re-analysis of the Nashville data.

Student Reports

M.J. CARUSO, Blood Donation Attitudes and Behavior, M.I.T. Operations Research Center Technical Report No. 139, February 1978.

This report examines aspects of behavior, attitudes, and decision processes pertaining to blood donation in three populations:

-A statistically controlled sample of the general public in three geographical areas (a total of 462 respondents from the Hartford, New York, and Houston metropolitan areas).

- Employees in a sample of working units in a particularly intense blood collection environment (a total of 508 respondents from three insurance companies in the Hartford area), and

- A sample of high school students at about the time many were exposed to their first opportunity to give blood at a Red Cross blood drive (a total of 1517 respondents from four high schools in eastern Massachusetts).

Respectively, the response rates for these survey activities were about 80%, 98%, and 90%.

This report is structured to provide comprehensive data in the tables and a discussion of major results in the text. The data tabulated may be of use for future research, and the text should be informative to people concerned with blood collection. Topics studied include: (1) willingness to give blood, (2) a profile of donation behavior, (3) the relative importance of reasons for donating and non donating, and (4) some implications of the findings to a blood collection strategy.

E.H. KAPLAN, Evaluating the Effectiveness of One- Versus Two-Officer Patrol Units, M.I.T. Operations Research Center Technical Report No. 153, June 1978.

This paper presents a model-based evaluation of one- versus two-officer patrol staffing. Postulated arguments for and against each strategy are outlined as they appear in the literature. Performance measures are elicited from this discussion. Several models are constructed which allow for a comparative analysis using these performance measures. Formal expectations of comparative strategic performance are presented at the end of the paper along with suggestions for further analytical research.

D.W. TALAFUSE, Blood Donor Attitudes and Decisions: An Exploratory Analysis, M.I.T. Operations Research Center Technical Report No. 137, February 1978.

The author reports on a pretest survey activity performed with samples of frequent and apparent former blood donors associated with each of four central blood collection programs. The survey instrument utilized is a self-administered mail questionnaire, concentrating on aspects of the respondent's first and most recent blood donations, on knowledge and attitudes about blood policy, and on some demographic characteristics.

Topics studied include:

1. The development of a better understanding of factors associated with the ways individuals begin and cease donating. How "reasons" for first donations vary among four locations, among frequent and former donors, and how such reasons have been changing over time are considered. For

the respondents, the lack of a perceived convenient donation opportunity is the single factor that best separates the frequent and former donors.

2. The relationship between blood collection systems and the attitudes and behavior of their participants. It was found that the ideology of individuals strongly reflects the ideology of their blood collector. It was found that the one community responsibility system in the study has as its most active donors people who donate much more frequently than is the case for the three individual responsibility systems. Surprisingly, little variation is found in the responses from each of the three individual responsibility systems. Donors from all systems speak very favorably of their most recent donation.

3. The ways in which male and female donors differ with regard to attitudes and donation behavior. Women are slightly more likely to give altruistic reasons for donation and they constitute a larger fraction of the ex-donors than of the frequent donors.

4. Consideration of several simple descriptive measures.

This report emphasizes the data analysis more than its possible interpretations. Several very important limitations on the results are noted. These include the complexity and low response rate associated with identifying and reaching former donors and the likely self-selection of respondents favoring people with positive dispositions toward the blood supply system.

2.2 Traffic and Transportation

Staff Reports

A.I. BARNETT, Control Strategies for Transport Systems with Nonlinear Waiting Costs, Transportation Science, May 1978.

The interaction between a transport company and its passengers is modelled as a cooperative game in which the company, subject to an economic constraint, uses the vehicle dispatch strategy under which a time-related cost function for passengers is minimized. A rudimentary transport system is studied in detail, and the joint optimal strategy for passengers and the transport company is obtained.

RESEARCH ACTIVITIES: Models and Applications

J.D.C. LITTLE, Maximal Bandwidth for Arterial Traffic Signals: Theory and Interactive Computation, M.I.T. Sloan School of Management Working Paper 970-78, September 1977.

The mixed-integer linear program introduced by Little for setting traffic signals to achieve maximal bandwidth is extended in several ways. One extension accommodates multiphase signals with leading or lagging greens, as for left turns, and permits the automatic choice of leads or lags. Another extension permits advancing the greenband to clear turn-traffic queues that accumulate during red.

The extensions are easily applied to arteries by means of an interactive computer program that operates on timesharing. Inputs are: distances between signals; upper and lower limits on cycle length; speed upper and lower limits; speed change limits; effective red times for each signal in each direction; bandwidth advances for clearing turn-traffic queues, and a value for the ratio of inbound-to-outbound bandwidth.

The program produces cycle time, offsets, speeds, and order of phases to maximize bandwidth. It also produces space-time diagrams for the artery.

Several further generalizations of the mixed-integer program are possible, including extension to networks. A 5-signal arterial problem based on a Boston area street illustrates the calculations.

T.L. MAGNANTI, Transportation Planning: Network Models and Their Implementation, (with B.L. Golden), M.I.T. Operations Research Center Technical Report No. 143, January 1978.

Transportation planning plays an essential role in shaping regional and urban lifestyle. Complex decisions regarding policy alternatives for railroads, shipping, airline, and roadway traffic can often be, and often have been, analyzed using network optimization techniques. This paper surveys applications of network algorithms to transportation planning, stressing network models and their efficient computer implementation. Recent contributions concerning shortest paths, minimum cost network flows, traffic equilibrium, vehicle routing, and network design are discussed and several open research problems are enumerated. Much of the discussion reflects an emerging theme in the analysis of transportation problems, the blending of ideas from transportation science, computer science, and operations research.

RESEARCH ACTIVITIES: Models and Applications

Student Reports

A.A. ASSAD, Analytical Models in Rail Transportation: An Annotated Bibliography, M.I.T. Operations Research Center Working Paper OR 066-77, October 1977.

This bibliography aims to collect the literature on analytical modelling of rail systems. Its scope covers the applications of operations research methods to rail. This has been a somewhat neglected area of research due to both the intimidating complexity of rail operations and the difficulty of establishing an interface between rail management and modellers with little specific knowledge of rail operations. The literature on rail modelling is rather scattered and mostly internal in nature. As a result few practitioners of operations research are sufficiently acquainted with issues of concern to rail operating management. This report attempts to provide an overview of the work already performed in this area.

A.A. ASSAD, Supply Modelling of Rail Networks: Toward a Routing/Make-up Model, M.I.T. Operations Research Center Working Paper OR 069-77, December 1977.

Freight flow management in rail systems involves multicommodity flows on a network complicated by node activities (queueing and classification of cars at marshalling yards). Routing in these systems should account for technology requirements of motive power and traction as well as resource allocation (cars to blocks, blocks to trains). This paper proposes a hierarchical taxonomy of modelling issues and describes a class of models dealing with car routing and train makeup from the viewpoint of network flows and combinatorial optimization. The model is compared with two previous rail network models and possibilities for algorithmic development are discussed.

M.L. BRANDEAU, Decision Strategies for Interline Subway Control Systems, SM in OR Thesis, February 1978.

This paper examines the class of subway control strategies known as "interline" control strategies. These are strategies which look not only at traffic flow along single lines, but also take into account coordination of passenger traffic between intersecting lines. Control is implemented by delaying trains at intersection points.

Three decision rules for determining whether or not to hold trains are studied using both simulation and analytical methods:

Rule 1: Never wait.
Rule 2: Wait if the distance to the next incoming train on the intersecting track is less than or equal to a specified cutoff.

Rule 3: Wait or do not wait depending on the values of the distance to the next following train on the same track and the distance to the next incoming train on the intersecting track.

The rules are first examined analytically in a single-intersection subway system with one-way traffic. Average passenger waiting times and passenger waiting time variances under each of the three strategies are compared. Illustrative data is used to highlight differences between the strategies. The effects of using linear cost functions for the passenger waiting time are considered. Results for non-linear cost functions are discussed.

The single-intersection model is studied using computer simulation to evaluate the three decision rules. Results are compared. A two-intersection simulation model is then studied.

It is concluded that an interline control strategy would provide significant service improvements by reducing both the mean and the variance of the passenger waiting time, while being relatively easy and inexpensive to implement. These preliminary results suggest the need for further research.

C. COZZI, Simple Models for a Single Route Public Transportation System, SM in OR Thesis, June 1978.

Several analytical models of the operation of a single route in a public transportation system are examined here. These models describe the system performance by the regularity of headways along the route. The first model assumes deterministic conditions and describes the effect of disturbances in the value of the parameters of the system on the regularity of the schedule. Dispatching headway and travel time disturbances are propagated and amplified at stops along the route by the passenger arrival and boarding process. Headway deviations of a vehicle will propagate to following vehicles. It is shown that the way the instability of schedule propagates to other vehicles depends on the value of the passenger arrival rate to boarding rate ratio.

The second and third models analyze the effect of random disturbances in dispatching headways and travel times on the regularity of headways along the route. Expressions predicting the variance of headways given the variance of the disturbances are derived. Predictions of these models are compared with the results of a simulation program. The phenomenon of vehicle clumping is analyzed and explanations of its causes and effects are proposed.

The effect of traffic lights on trip time is examined in the last model. Expressions for the mean and variance of total delay based on the spatial distribution and operating characteristics of the traffic lights are proposed.

RESEARCH ACTIVITIES: Models and Applications

S.E. ERIKSEN, Policy Oriented Multi-Equation Models of U.S. Domestic Air Passenger Markets, PhD in OR Thesis, September 1977.

The airline industry in recent years has suffered from the adverse effects of top level planning decisions based upon inaccurate demand forecasts. The air carriers have recognized the immediate need to develop their forecasting abilities and have applied considerable talent to this area. However, their forecasting methodologies still are far below the level of sophistication of their other planning tools. The purpose of this paper is to develop a set of demand models which are sufficiently sensitive to measure the effects upon demand policy decisions with respect to such variables as fare and technological and quality of service factors.

A brief overview of transportation demand theory and a survey of recently published research in air passenger demand modeling are presented. Following these is a discussion of the economic nature of domestic air transportation passenger service indicating the demand and service attributes and how they interact in equilibrium. Based upon this background information a multi-equation econometric model is developed. The model is calibrated over subsets of a base of historical data from 180 markets over a six year time frame. The subsets are cross classifications of markets with respect to length of haul and market size. Recently developed techniques in model sensitivity analysis are applied to ensure statistical robustness, and principal components regression is employed to combat the problem of multicollinearity. Numerical examples of applications of the model are provided.

The results indicate that the model performs very well in the analysis of long and medium haul markets. It is particularly effective in the higher density markets. The model is not equipped to account for the impacts upon air transportation passenger demand of competing modes, and therefore does not perform well in the analysis of short haul (less than 400 miles) markets.

G. SADIQ, Multifleet Routing Problem, SM in OR Thesis, February 1978.

The multifleet routing problem refers to the optimization of vehicle scheduling in a given schedule map when there are different types of vehicles in the fleet as regards to the capacity, operating cost and range. The vehicle may be an aircraft, a train, a subway or bus. However, the problem is especially significant to the airlines for schedule planning for future years, investment decisions and in the situation of a technical breakdown of an aircraft.

The problem has been attempted using linear programming, Dantzig-Wolfe decomposition, set partitioning and other algorithms which exploit

the special structure of the multifleet routing problem. Examples have been solved by each of the mentioned techniques and the computational results and conclusions are presented.

D.P. WEILMUENSTER, Performance Characteristics of Signpost Automatic Vehicle Locating Systems, SM in OR Thesis, September 1977.

Automatic vehicle locating (AVL) systems are being proposed and implemented in various cities to improve the operations of transit systems and police forces by estimating the true locations of their constituent units for the dispatchers who manage them. As the number of AVL techniques increases, effective and comparable performance measures must be developed for the competing systems to facilitate informed choices among them. This task is undertaken here for signpost AVL's which update a vehicle's position each time it passes one of many low range sensors deployed at intersections throughout a city. The types of vehicles considered are those whose driving paths are perceived as random by outside observers. Examples are police vehicles on preventive patrol or dial-a-bus units en route to known destinations but without specified itineraries. First, a Markov model for the traveling behavior of such vehicles is inferred from data generated by police cars in St. Louis, Missouri and interpreted as a random walk. A Central Limit Theorem is derived for the location distribution of vehicles so described as they travel on infinite street systems. Next, a distribution is presented for ν, the number of blocks driven by vehicles between sensings. This statistic is inversely related to the update rate of signpost AVL systems. It is shown for general classes of signpost AVL's that the mean value for ν is the reciprocal of the steady state probability that a vehicle is at an intersection with a signpost. Coefficients of variation for ν are calculated as a function of parameters in the model for travel for several infinite sensor lattices. Last, a distribution is developed for the location error in signpost AVL's, defined as the distance between a vehicle's true and estimated positions. Examples of the computations required to obtain the error distribution are presented for several different signpost arrays imbedded in a realistic four by six block urban area. These computational procedures are easily applied to arbitrarily complex urban regions containing at most a few hundred distinct street segments.

2.3 Industrial and Management Systems

Staff Reports

S.C. GRAVES, A Note of the Deterministic Demand Multi-Product Single-Machine Lot Scheduling Problem, M.I.T. Operations Research Center Technical Report No. 140, January 1978.

This note considers two single-machine multi-product scheduling problems with deterministic demand that have appeared in the management science literature: the economic lot scheduling problem and the joint replenishment problem. These problems are shown to be equivalent. In addition, they are shown to be equivalent to a one-warehouse, several-retailer inventory problem for which exists an efficient branch and bound solution procedure.

S.C. GRAVES, Simple Analytical Models for Perishable Inventory Systems, M.I.T. Operations Research Center Technical Report No. 141, January 1978.

This paper develops three distinct models for studying perishable inventory systems. The perishable items have a deterministic usable life after which they must be outdated. For each of the models, analytical expressions are found for steady-state distributions which characterize the inventory systems. Knowledge of this steady-state behavior may be used for evaluation of system performance, and for consideration of alternatives for improving system performance.

The first model considered assumes that both the demand process and the inventory replenishment process are stochastic processes that may be modelled as Poisson processes. The second and third model assume that inventory is replenished by a constant production process. The second model, assuming continuous inventory units, has Poisson demand requests with the size of each request distributed as an exponential random variable. The third model has Poisson demand requests with all demands being for a single unit.

S.C. GRAVES, The Multi-Product Production Cycling Problem: Development of Heuristics, M.I.T. Operations Research Center Technical Report No. 146, March 1978.

The multi-product production cycling problem is concerned with the determination of a production/inventory policy for a single capacitated production facility which is dedicated to producing a family of products. This paper studies this problem assuming stochastic demand. The one-product problem is formulated as a Markov decision problem

which may be reasonably solved. For the multi-product problem, heuristic decision rules are proposed. In the context of an identical-product problem, a heuristic decision policy is developed which is based on the analysis of the one-product problem, and on two new notions: the composite product and the lead-time adjustment. This heuristic is then extended to the identical-cost problem, and the correlated demand problem. Arguments are presented for the generality of the identical-cost problem, and hence the generality of the proposed heuristic policy.

S.C. GRAVES, The Multi-Product Production Cycling Problem: Testing of Heuristics, M.I.T. Operations Research Center Technical Report No. 147, March 1978.

The multi-product production cycling problem is concerned with the determination of a production/inventory policy for a single capacitated production facility which is dedicated to producing a family of products. In an earlier paper, heuristic policies were proposed for various versions of the multi-product problem. This paper tests the effectiveness of these heuristics by simulation. It is seen that the proposed heuristic utilizing composite products and the lead-time adjustment, is the most effective of the heuristics considered over the set of test problems for the identical-product problem. Likewise, the composite product heuristic is the best heuristic for the identical-cost problem and the correlated demand problem.

S.C. GRAVES, A One-Product Production/Inventory Problem under Continuous Review Policy, (with B. Gavish), University of Rochester Graduate School of Management Working Paper 7735, November 1977.

A single production facility is dedicated to producing one type of product with completed units going directly into inventory. The demand for the product is governed by a Poisson process and is supplied directly to inventory when available, or is backordered until it is produced by the production facility. Relevant costs are a linear inventory holding cost, a linear backorder cost, and a fixed setup cost for initiating a production run. The objective function is to find a production/inventory policy that will minimize the expected cost per time unit. Usually the questions of production scheduling and of inventory control are separated. This paper combines the two problems and optimizes them simultaneously.

It is shown that the problem may be modeled as a M/D/1 queueing system. The optimal decision policy for this queueing problem is given by a two-critical-number policy. Cost expressions are derived as functions of the policy parameters, and based on a convexity property of these cost expressions, a search procedure is proposed for finding the optimal policy. Computational test results demonstrating the efficiency of the search procedure and the behavior of the optimal policy are presented.

RESEARCH ACTIVITIES: Models and Applications

S.C. GRAVES, Scheduling Policies for Automatic Warehousing Systems: Simulation Results, (with L.B. Schwarz and W.H. Hausman), Stanford University Department of Industrial Engineering and Engineering Management Technical Report No. 77-4, September 1977.

This paper examines and extends previous analytical work on the scheduling of stacker cranes in automatic warehousing systems. In particular, the following are examined by means of a computer simulation:

(1) The performance of the closest-open-location rule compared to random storage assignment;

(2) The dynamic behavior of the system under stochastic conditions, using various crane and rack utilization levels;

(3) The actual versus predicted reduction in crane travel time due to improved scheduling rules;

(4) The effect of imperfect information concerning the length of stay of an incoming pallet on system performance.

The results of the experiments provide evidence in support of the proposed analytical models. They also demonstrate the value of previously proposed scheduling rules in a dynamic, stochastic environment operating with imperfect information.

A.C. HAX, Hierarchical Production Planning Systems, (with J.J. Golovin), M.I.T. Operations Research Center Technical Report No. 135, August 1977.

This paper describes the development of hierarchical planning systems to support medium range planning and operational decisions in a batch processing production environment. In this approach, higher level decisions impose constraints to lower level actions, and lower level decisions provide the necessary feedback to reevaluate higher level actions. An analysis of the existing methodology to design hierarchical production systems is given. Computational results are presented.

A.C. HAX, Towards the Formalization of Strategic Planning - A Conceptual Approach, (with N.S. Majluf), M.I.T. Sloan School of Management Technical Report No. 2, August 1977.

This paper attempts to present a general framework for the strategic planning process in complex organizations, with special emphasis in diversified business corporations. It has to be recognized that a specific strategic plan has to be designed to fit the particular conditions of the corresponding situational setting. Consequently, it is not intended in this paper to push the general validity of this framework, but to make available a set of concepts, steps, and variables

that may suggest creative strategic options, and could provide an orderly strategic planning process in a business firm.

J.D.C. LITTLE and J.F. SHAPIRO, A Theory for Pricing Non-Featured Products in Supermarkets, M.I.T. Sloan School of Management Working Paper 931-77, April 1978.

Of the 6,000 products in the average supermarket, a few receive special advertised prices in a given week, but the great majority are assigned prices by standard percentage markups within category, adjusted, if necessary, for competitive conditions and special price endings. Notably missing in setting prices is any direct consideration of actual customer price response.

The advent of the Universal Product Code and inexpensive, machine readable sales data promises to make possible the wide-spread determination of customer price response by in-store experiment. This in turn, opens up the possibility of developing and implementing a more powerful theory for setting prices. Yet, it would probably be disastrous for a store to set price in a simple profit-maximizing way based on such in-store measurements. The reason is that the customer may pay a high price once and then not come back to the store, thereby creating a small temporary gain and a large permanent loss.

A two-stage theory addresses this issue by postulating that customers once in the store purchase goods to maximize their utility. This determines observable in-store customer price response. The store then maximizes its profit subject to a constraint on customer utility delivered. The level of the constraint becomes a policy parameter that determines, in part, the attractiveness of the store to the customer.

It is shown that under this theory, the store can set prices using a formula containing only empirical measurements and a single store-wide policy parameter. The prices so obtained are efficient in that, for a given level of store profit, no other set of prices will permit higher consumer utility and, conversely, for a given level of customer utility, no other prices will permit higher store profit.

Student Reports

D. CANDEA, Issues of Hierarchical Planning in Multi-Stage Production Systems, M.I.T. Operations Research Center Technical Report No. 134, July 1977.

The multi-stage production system is viewed as a production process in which component parts have to be obtained by manufacturing or by

purchasing, then assembled into subassemblies, assemblies, and finally into the finished good.

The problem and its characteristics are described, and the principal difficulties associated with this kind of problems are identified. Both computational and managerial aspects are discussed and used to motivate the adoption of the hierarchical approach to production planning. According to this approach, the overall problem is partitioned into two levels: the aggregate level and the detailed (or disaggregation) level.

At the aggregate level a new formulation for the aggregate planning model is given, in order to bring computational feasibility to situations in which older formulations went beyond the capabilities of current linear programming codes. The resulting aggregate model is a large scale system that lends itself to solution by column generation. A dynamic programming algorithm for the generation of columns is developed.

Next, at the disaggregation level, the problem of computing optimal lot sizes in multi-stage systems is addressed and solved. Since exact solution procedures are found to be either very expensive or computationally infeasible, a heuristic approach is adopted and results are reported. For more complex situations, in which parts are common to several end products or where there is independent demand for parts, even the heuristics become infeasible; therefore it is suggested that myopic lot sizing policies be used.

The issue of safety stocks for aggregate planning is treated in another chapter. The impact of the rolling horizon policy upon safety stocks is first examined in the simpler setting of single stage production. Then, the sources of uncertainties in multi-stage systems are identified and ways to build protection against them are developed.

In the concluding chapter a number of research topics, which are worth investigating in the author's opinion, are indicated.

2.4 Energy and Economic Systems

Staff Reports

J.F. SHAPIRO, Models for Planning Investments in Electric Power and Water Supply in Saudi Arabia, (with A. Kazmi), Energy Use Management, Volume 1, Pergamon Press, 1977, pp. 873-878.

This paper reports on a MIP model for optimally selecting the timing, sizing and location of plants to co-generate fresh water and electricity

from steam. Single purpose plants are also options in the model. The model uses as inputs population and demand data from a systems dynamics forecasting model and construction and operating costs from an engineering model. The model has been successfully implemented for general regions of Saudi Arabia.

J.F. SHAPIRO, Integration of Nonlinear Coal Supply Models and the Brookhaven Energy System Optimization Model (BESOM), (with D.E. White), M.I.T. Operations Research Center Working Paper OR 071-78, January 1978.

This is a report on efforts to date to integrate BESOM, or one of the other energy planning models based on it, Hoffman (1972), Cherniavsky (1974), or Goettle et al (1977), with nonlinear supply models developed at the M.I.T. Energy Laboratory. Experimentation and conceptualization of the integration process has thus far been primarily with BESOM and Zimmerman's coal supply model (Zimmerman (1977)). The technical difficulties in achieving the integration, and the methods for overcoming them, are applicable to similar efforts with other energy supply models (e.g., the oil and gas model of MacAvoy and Pindyck (1975)).

The plan of this report is as follows: Section 2 contains the results of sensitivity analyses on primary energy supplies in the current version of BESOM. Section 3 gives a description of Zimmerman's coal supply model in mathematical programming terms, followed by a discussion of decomposition methods for solving it and integrating it with other energy models. Some concluding remarks are given in Section 4. There is one Appendix giving more detail about the sensitivity analyses performed.

Student Reports

J.A. BLOOM, Optimal Generation Expansion Planning for Electric Utilities using Decomposition and Probabilistic Simulation Techniques, M.I.T. Operations Research Center Working Paper OR 064-77, August 1977.

Three related methods are presented for determining the least-cost generating capacity investments required to meet given future demands for electricity. The models are based on application of large-scale mathematical programming decomposition techniques. In the first method, decomposition techniques are applied to linear programming models such as those presented by Anderson (Bell Journal of Economics, Spring 1972). An important result is that the subproblems, representing optimal operation of a set of plants of given capacity each year, can be solved essentially by inspection. In the second method, decomposition is applied to an equivalent non-linear programming model, with the same result that the subproblems are very simple to solve. The third method extends the second to include the probabilistic simulation technique of Baleriaux and Booth (IEEE Transactions on Power Apparatus and Systems, Jan.-Feb., 1972), which determines the optimal operating costs

when plants can fail randomly. Though the model is non-linear, the subproblems involving the probabilistic simulation can be solved without using non-linear programming.

D.P. ELLIOTT, Planning Investments in Water Resources by Mixed Integer Programming: The Vardar-Axios River Basin, M.I.T. Operations Research Center Working Paper OR 072-78, March 1978.

A mixed integer programming model for planning water resources investments is presented. The model is a sequencing model applied to the Vardar-Axios river basin in Yugoslavia and Greece. The structure of the model is outlined, and computational experience is described. The size of the model presented some difficulties, which are discussed along with the results to date. The experience with this model points to areas where further research is needed.

E.M. MODIANO, Normative Models of Depletable Resources, PhD in OR Thesis, June 1978. Also, M.I.T. Operations Research Center Technical Report No. 151, June 1978.

The major theme of this work is the integration of depletable resources supply and sectoral dynamic models. These models are inherently normative due to their mathematical programming formulations. The economic sectors that demand the depletable resource minimize in each time period the cost of meeting the demand for end-use goods. The suppliers allocate the fixed resource stock over time such as to maximize the net present value of profits. Equilibrium is defined by linking the suppliers' revenue with sectoral savings in costs. Mathematical programming concepts, particularly decomposition methods, facilitate the integration of these models. Some extensions are discussed and implemented in this context: essential versus inessential resources, the existence of institutional agents and capacity constraints on resource extraction.

The existence of equilibrium in the case of multiple collusive and competing economic agents is also considered. Competing multiple depletable resource suppliers create several difficulties in the basic framework. These are also mentioned. Models are developed to consider the major source of uncertainties in depletable resource intertemporal planning: technological transition, end-use demands and resource reserves. The techniques used are dynamic programming, linear programming with recourse and Markovian decision theory, respectively.

Finite-horizon approximation methods for the case of infinite planning horizons are presented. These are of particular interest in the integration of transient and stationary stage models. Leontief substitution systems are also considered. Finite-elasticities in the demand for end-use goods and the supply of alternative primary supplies add more flexibility to the equilibrium model. Linear relationships can be effectively handled by the development of parametric quadratic programming.

RESEARCH ACTIVITIES: Models and Applications

S. PARIENTE, A Model for the Efficient Use of Energy Resources, M.I.T. Operations Research Center Working Paper OR 067-77, November 1977.

This paper illustrates the application of mathematical programming to formulate and solve a simple energy planning problem. The energy system is represented as a network where energy flows from sources to end uses. The model formulated is dynamic and takes explicitly into account the depletion over time of fossil fuels. The problem is to determine, given an existing technology, the minimum cost flow of resources. It is a subproblem of the more complex long term problem of choosing an optimal set of technologies.

S. PARIENTE, Mathematical Programming Approaches to Modelling Technological Change, with Applications to the Energy Sector, PhD in OR Thesis, June 1978. Also, M.I.T. Operations Research Center Technical Report No. 148, April 1978.

Mathematical programming provides a useful methodology to assess and select new technologies, while recognizing the important economic impact of technological innovations and the lumpiness of R&D processes. After discussing an abstract model for selection of an optimal technology set (a fixed charge Leontief model), the approach is illustrated by applying it to a problem in the energy sector. The energy system is represented as a network where energy flows from sources to end uses. The model formulated is dynamic and takes explicitly into account the depletion over time of fossil fuels. The first problem is to determine, given an existing technology set, the minimum cost flow of energy in each period and also the optimal depletion path of energy resources. The model is then extended to include energy R&D activities that generate new technologies. The second problem is to determine the optimal development of these new energy technologies.

RESEARCH ACTIVITIES: Models and Applications

3. Computation

Staff Reports

G.R. BITRAN, Experiments with Linear Fractional Problems, M.I.T. Operations Research Center Technical Report No. 149, April 1978.

The results of a limited number of experiments with linear fractional problems are presented. Six solution procedures were tested and the results are expressed in number of simplex-like pivots required to solve a sample of twenty problems randomly generated.

R.E. WELSCH, Tables for Stepwise Multiple Comparison Procedures, M.I.T. Sloan School of Management Working Paper 949-77, August 1977.

This paper presents tables for $\alpha = .05$ and degrees of freedom equal to 5(1)20, 24, 30, 40, 60, 120, and ∞ for the multiple comparison procedures discussed in the article "Stepwise Multiple Comparison Procedures" by Roy E. Welsch in the September 1977 issue of the Journal of the American Statistical Association.

R.E. WELSCH, An Adaptive Nonlinear Least-Squares Algorithm, (with J.E. Dennis, Jr. and D.M. Gay),M.I.T. Operations Research Center Technical Report No. 142, January 1978.

NL2SOL is a modular program for solving the nonlinear least-squares problem that incorporates a number of novel features. It maintains a secant approximation S to the second-order part of the least-squares Hessian and adaptively decides when to use this approximation. The authors have found it very helpful to "size" S before updating it, something which looks much akin to Oren-Luenberger scaling. Rather than resorting to line searches or Levenberg-Marquardt modifications, the double-dogleg scheme of Dennis and Mei is used together with a special module for assessing the quality of the step thus computed. These and other ideas behind NL2SOL are discussed and its evolution and current implementation is described briefly.

R.E. WELSCH, The Hat Matrix in Regression and ANOVA, (with D.C. Hoaglin), The American Statistician, 32, February 1978, pp. 17-22.

In least-squares fitting it is important to understand the influence which a data y value will have on each fitted y value. A projection matrix known as the hat matrix contains this information and, together with the Studentized residuals, provides a means of identifying exceptional data points. This approach also simplifies the calculations involved in removing a data point, and it requires only simple modifications in the preferred numerical least-squares algorithms.

R.E. WELSCH, Robust Regression Using Iteratively Reweighted Least-Squares, (with R.W. Holland), Communications in Statistics, A6, 1977, PP. 813-827.

The rapid development of the theory of robust estimation (Huber, 1973) has created a need for computational procedures to produce robust estimates. A number of different computational approaches for robust linear regression are reviewed but the focus is on one--iteratively reweighted least-squares (IRLS). The weight functions that are discussed are a part of a semi-portable subroutine library called ROSEPACK (RObust Statistical Estimation PACKage) that has been developed by the authors and Virginia Klema at the Computer Research Center of the National Bureau of Economic Research, Inc. in Cambridge, Mass. with the support of the National Science Foundation. This library (Klema, 1976) makes it relatively simple to implement an IRLS regression package.

III. EDUCATIONAL ACTIVITIES

A. Subjects Offered by Operations Research Center Staff 1977-78

Subject Number	Subject Title	Instructor	Term	Enrollment
1.203	Transportation Supply Models	T.L. Friesz A.R. Odoni	Spring	12
6.041	Probabilistic Systems Analysis	A.W. Drake	Summer	43
6.041	Probabilistic Systems Analysis	A.W. Drake	Fall	160
6.041	Probabilistic Systems Analysis	A.W. Drake	Spring	165
6.262	Advanced Markov Models and Their Applications	A.W. Drake R.C. Larson	Spring	19
6.281J 11.526J 15.078J 16.76J	Urban Operations Research	A.I. Barnett R.C. Larson	Spring	13
6.431	Applied Probability	A.W. Drake	Summer	16
6.431	Applied Probability	A.W. Drake	Fall	25
6.431	Applied Probability	A.W. Drake	Spring	22
6.432	Stochastic Processes and Applications	R.C. Larson	Fall	30
6.452	Stochastic Filtering and Detection	S.K. Mitter	Spring	23
11.523	Evaluation of Public Programs	R.C. Larson M. Rein	Fall	13
15.015	Quantitative Approaches to Economic and Management Policy	R.S. Pindyck D.R. Lessard J.F. Shapiro	Spring	8
15.053	Introduction to Management Science	J.D.C. Little	Fall	57

EDUCATIONAL ACTIVITIES: Subjects Offered

Subject Number	Subject Title	Instructor	Term	Enrollment
15.061	Mathematics for Management I	A.I. Barnett	Fall	76
15.061	Mathematics for Management I	R.E. Welsch	Spring	27
15.062	Mathematics for Management II	J.F. Shapiro	Fall	54
15.062	Mathematics for Management II	S.C. Graves	Spring	73
15.063J 18.457J	Statistics for Modeling Building	R.E. Welsch H. Chernoff	Spring	21
15.073J 18.445J	Introduction to Stochastic Processes	A.I. Barnett	Spring	32
15.075	Statistics for Applications	R.E. Welsch	Fall	53
15.081	Mathematical Programming	T.L. Magnanti	Fall	25
15.081	Mathematical Programming	J.A. Bloom	Spring	25
15.083	Combinatorial Optimization	J.F. Shapiro	Spring	7
15.084J 6.251J	Mathematical Programming and Discrete Time Optimal Control	T.L. Magnanti S.K. Mitter	Fall	32
15.099	Management Science Seminar	J.D.C. Little	Fall	7
15.761	Operations Management	G.R. Bitran A.C. Hax	Spring	83
15.781	Capacity Planning: Production and Distribution Systems	S.C. Graves	Fall	12

EDUCATIONAL ACTIVITIES: Subjects Offered

Subject Number	Subject Title	Instructor	Term	Enrollment
15.791	Operations Planning and Control Systems	S.C. Graves	Spring	7
15.795	Seminar in Operations Management	A.C. Hax	Fall	17
15.795	Seminar in Operations Management	A.C. Hax	Spring	14
15.963	Network Optimization	T.L. Magnanti	Spring	45
16.701	Principles of Systematic Policy Analysis	A.R. Odoni	Fall	25
16.702	Seminar in Systematic Policy Analysis	A.R. Odoni	Spring	14
16.72	Air Traffic Control	W. Hollister A.R. Odoni	Spring	6
16.751	Flight Transportation	A.R. Odoni	Fall	17

EDUCATIONAL ACTIVITIES

B. Operations Research Seminars

The Operations Research Center seminar series provides an opportunity for students and faculty to hear speakers on operations research from inside and outside M.I.T. All seminars are open to the M.I.T. community and the public. They are often general in content and so provide undergraduates and beginning graduate students with a perspective on O.R. activity.

Samuel S. Chiu and Paulo A. Villela were the Seminar Coordinators for the year.

September 27	Prof. Herman Chernoff Department of Mathematics M.I.T. Cambridge, Massachusetts	A Satellite Control Problem
October 20	Prof. Eric V. Denardo School of Organization and Management Yale University New Haven, Connecticut	Optimal Stopping, Exponential Utility and Linear Programming
November 1	Dr. C.L. Mallows Bell Laboratories Holmdel, New Jersey	Some Theory of Non-Linear Squares
November 10	Prof. Howard Morgan The Wharton School University of Pennsylvania Philadelphia, Pennsylvania	Optimizing Distributed Data Bases in Computer Networks
December 1	Prof. C.H. Papadimitriou Aiken Computational Laboratory Harvard University Cambridge, Massachusetts	Optimization Problems and Computational Complexity
December 15	Prof. Elon Kohlberg Graduate School of Business Administration Harvard University Boston, Massachusetts	On a Simple Recursion Equation

EDUCATIONAL ACTIVITIES: O.R. Seminars

January 10	Prof. Stephen C. Graves Sloan School of Management M.I.T. Cambridge, Massachusetts	Stochastic Modeling Applied to Three Production and Inventory Problems
January 12	Prof. Bruce H. Faaland School of Business University of Washington Seattle, Washington	Interior Path Methods for Heuristic Integer Programming Procedures
January 17	Prof. Thomas R. Willemain Department of Urban Studies and Planning M.I.T. Cambridge, Massachusetts	How Many Nursing Homes are Enough?
January 19	Prof. Paul Berger School of Management Boston University Boston, Massachusetts	Prediction Problems with Loss Structure Considerations
January 24	Prof. Arnold I. Barnett Sloan School of Management M.I.T. Cambridge, Massachusetts	Death at an Early Age
January 26	Dr. Ashok Kalelkar Operations Research Section Arthur D. Little, Inc. Cambridge, Massachusetts	Risk Measurement as a Decision Parameter in the Transportation of Hazardous Chemicals by Rail
January 31	Prof. Thomas L. Magnanti Sloan School of Management M.I.T. Cambridge, Massachusetts	Optimization, Operations Research and Economics
February 14	Prof. Peter Caines Division of Applied Sciences Harvard University Cambridge, Massachusetts	Stochastic Dynamical System Identification
February 23	Prof. Jack Edmonds Department of Combinatorics and Optimization University of Waterloo Waterloo, Ontario	Dual Integrality and Nice Discrete Optimizations: An Introductory Survey Talk

EDUCATIONAL ACTIVITIES: O.R. Seminars

February 28	Dr. Ralph L. Keeney Decision Analysis Group Woodward-Clyde Consultants San Francisco, California	Evaluation Involving Potential Fatalities
March 16	Prof. Michael Todd School of Operations Research and Industrial Engineering Cornell University Ithaca, New York	Special Structures in Fixed Point Problems
April 6	Prof. Saul I. Gass College of Business and Management University of Maryland College Park, Maryland and Mr. Paul S. Levy National Highway Traffic Safety Administration U.S. Department of Transportation Washington, D.C.	Modeling and Analysis for Traffic Safety
April 13	Dr. John G. Pierce Exploratory Research Division Center for Naval Analysis Arlington, Virginia	Information Theory and Search Theory: A New Look at Their Relationship
April 20	Prof. Donald G. Morrison Graduate School of Business Columbia University New York, New York	The Application of Some Probability Mixture Models in Analyzing Social Science Data
May 4	Prof. Mark Thompson Harvard School of Public Health Harvard University Boston, Massachusetts	Topics in Benefit-Cost Analysis

EDUCATIONAL ACTIVITIES

C. O.R. Theses Completed

Author	Supervisor
O. BERMAN, "Dynamic Positioning of Mobile Servers on Networks," Ph.D., February 1978.	A.R. Odoni R.C. Larson
M.L. BRANDEAU, "Decision Strategies for Interline Subway Control Systems," S.M., February 1978.	R.C. Larson
C. COZZI, "Simple Models for a Single Route Public Transportation System," S.M., June 1978.	R.C. Larson
S.E. ERIKSEN, "Policy Oriented Multi-Equation Models of U.S. Domestic Air Passenger Markets," Ph.D., September 1977.	N.K. Taneja
W.G. GOLUSH, "Probabilistic Models for Optimal Seismic Design," S.M., February 1978.	D. Veneziano
E.M. MODIANO, "Normative Models of Depletable Resources," Ph.D., June 1978.	J.F. Shapiro
S. PARIENTE, "Mathematical Programming Approaches to Modelling Technological Change, with Applications to the Energy Sector," Ph.D., June 1978	J.F. Shapiro
G. SADIQ, "Multifleet Routing Problem," S.M., February 1978.	R.W. Simpson
W.B. SHEPARDSON, "A Lagrangean Relaxation Algorithm for the Two Duty Period Scheduling Problem, Ph.D., June 1978.	T.L. Magnanti
D.P. WEILMUENSTER, "Performance Characteristics of Signpost Automatic Vehicle Locating Systems," S.M., September 1977.	R.C. Larson

IV. PROFESSIONAL ACTIVITIES

A. Publications

A.A. ASSAD, "Analytical Models in Rail Transportation: An Annotated Bibilography," Working Paper OR 066-77, M.I.T. Operations Research Center, October 1977.

A.A. ASSAD, "Supply Modelling of Rail Networks: Toward a Routing/Make-Up Model," Working Paper OR 069-77, M.I.T. Operations Research Center, December 1977.

A.I. BARNETT, "Control Policies for Transport Systems with Nonlinear Waiting Costs," Transportation Science, May 1978.

A.I. BARNETT and D.J. KLEITMAN, "Some Optimization Problems with Bulk-Service Queues," Studies in Applied Mathematics, 58, June 1978, pp. 277-290.

O. BERMAN, "Dynamic Positioning of Mobile Servers on Networks," Technical Report No. 144, M.I.T. Operations Research Center, January 1978.

G.R. BITRAN, "Linear Multiple Objective Programs with Zero-One Variables," Mathematical Programming, 13, 1977, pp. 121-139.

G.R. BITRAN, "Experiments with Linear Fractional Problems," Technical Report No. 149, M.I.T. Operations Research Center, April 1978.

G.R. BITRAN, "Theory and Algorithms for Linear Multiple Objective Programs with Zero-One Variables," Technical Report No. 150, M.I.T. Operations Research Center, May 1978.

G.R. BITRAN and T.L. MAGNANTI, "The Structure of Admissible Points with Respect to Cone Dominance," Working Paper OR 074-78, M.I.T. Operations Research Center, April 1978.

J.A. BLOOM, "Optimal Generation Expansion Planning for Electric Utilities Using Decomposition and Probabilistic Simulation Techniques," Working Paper OR 064-77, August 1977.

D. CANDEA, "Issues of Hierarchical Planning in Multi-Stage Production Systems," Technical Report No. 134, M.I.T. Operations Research Center, July 1977.

D.W. CARLTON and J. FERREIRA, JR., "Selecting Subsidy Strategies for Housing Allowance Programs," Journal of Urban Economics, 4, July 1977, pp. 221-247.

PROFESSIONAL ACTIVITIES: Publications

M.J. CARUSO, "Blood Donation Attitudes and Behavior," Technical Report No. 139, M.I.T. Operations Research Center, February 1978.

J.E. DENNIS, D.M. GAY and R.E. WELSCH, "An Adaptive Nonlinear Least-Squares Algorithm," Technical Report No. 142, M.I.T. Operations Research Center, January 1978.

D.P. ELLIOTT, "Planning Investments in Water Resources by Mixed Integer Programming: The Vardar-Axios River Basin," Working Paper OR 072-78, M.I.T. Operations Research Center, March 1978.

B. GAVISH and S.C. GRAVES, "A One-Product/Production Inventory Problem under Continuous Review Policy," Working Paper 7735, University of Rochester Graduate School of Management, November 1977.

C.S. GOODRICH and A.W. DRAKE, "Comments about Blood Donation: Nondonor, Exdonor, and Recent Donor Responses to Some Open-Ended Questions," Technical Report No. 136, M.I.T. Operations Research Center, October 1977.

S.C. GRAVES, "A Note of the Deterministic Demand Multi-Product Single-Machine Lot Scheduling Problem," Technical Report No. 140, M.I.T. Operations Research Center, January 1978.

S.C. GRAVES, "Simple Analytical Models for Perishable Inventory Systems," Technical Report No. 141, M.I.T. Operations Research Center, January 1978.

S.C. GRAVES, "The Multi-Product Production Cycling Problem: Development of Heuristics," Technical Report No. 146, M.I.T. Operations Research Center, March 1978.

S.C. GRAVES, "The Multi-Product Production Cycling Problem: Testing of Heuristics," Technical Report No. 147, M.I.T. Operations Research Center, March 1978.

A.C. HAX, "Aggregate Production Planning," in Handbook of Operations Research: Models and Applications, Volume II, J. Moder and S.E. Elmaghraby (eds.), Van Nostrand Publishing Company, 1978, pp. 127-172.

A.C. HAX and J.J. GOLOVIN, "Hierarchical Production Planning Systems," Technical Report No. 135, M.I.T. Operations Research Center, August 1977.

A.C. HAX and N. MAJLUF, "Towards the Formalization of Strategic Planning - A Conceptual Approach," Technical Report No. 2, M.I.T. Sloan School of Management, August 1977.

A.C. HAX and K.M. WIIG, "The Use of Decision Analysis in Capital Investment Problems," in Conflicting Objectives in Decisions, D.E. Bell, R.L. Keeney and H. Raiffa (eds.), John Wiley and Sons, 1977, pp. 277-297.

PROFESSIONAL ACTIVITIES: Publications

A.C. HAX and Z. ZENNETOS, "The Conglomerate Firm," Technical Report No. 5, M.I.T. Sloan School of Management, June 1978.

D. HOAGLIN and R.E. WELSCH, "The Hat Matrix in Regression and ANOVA," The American Statistician, 32, 1978, pp. 17-22.

P. HOLLAND and R.E. WELSCH, "Robust Regression Using Iteratively Reweighted Least Squares," Communications in Statistics, 6, 1977, pp. 813-827.

E.H. KAPLAN, "Evaluating the Effectiveness of One- Versus Two-Officer Patrol Units," Technical Report No. 153, M.I.T. Operations Research Center, June 1978.

B.W. LAMAR, "What the Textbooks Say About the Design of Experiments," Working Paper OR 073-78, M.I.T. Operations Research Center, March 1978.

R.C. LARSON, "Structural System Models for Locational Decisions: An Example Using the Hypercube Queueing Model," Technical Report No. 145, M.I.T. Operations Research Center, March 1978.

R.C. LARSON (ed.), Police Deployment: New Tools for Planners, Lexington Books, 1978.

R.C. LARSON, "The Hypercube Queueing Model: An Introduction to its Structure and Utility," in Police Deployment: New Tools for Planners, R.C. Larson (ed.), Lexington Books, 1978.

R.C. LARSON, "The Hypercube Queueing Model: Illustrative Police Sector Redesign," in Police Deployment: New Tools for Planners, R.C. Larson (ed.), Lexington Books, 1978.

R.C. LARSON, "The Hypercube Queueing Model: Uses," in Police Deployment: New Tools for Planners, R.C. Larson (ed.), Lexington Books, 1978.

R.C. LARSON (ed.), Police Accountability: Performance Measures and Unionism, Lexington Books, 1978.

R.C. LARSON and E.A. FRANCK, "Evaluating Dispatching Consequences of Automatic Vehicle Location in Emergency Services," Journal of Computers and Operations Research, 5, 1978, pp. 11-30.

J.D.C. LITTLE, "Maximal Bandwidth for Arterial Traffic Signals: Theory and Interactive Computation," Working Paper 970-78, M.I.T. Sloan School of Management, September 1977.

PROFESSIONAL ACTIVITIES: Publications

J.D.C. LITTLE, "Modelle und Manager: Das Konzept des Decision Caculus," in Entscheidungshilfen im Marketing, R. Kohler and H.J. Zimmerman (eds.), C.E. Poeschel Verlag, 1977, pp. 122-147.

J.D.C. LITTLE, "Models and Managers: The Concept of a Decision Calculus," in Behavioral and Management Science in Marketing, H.L. Davis and A.J. Silk (eds.), John Wiley and Sons, 1978.

J.D.C. LITTLE and J.F. SHAPIRO, "A Theory for Pricing Non-Featured Products in Supermarkets," Working Paper 931-77, M.I.T. Sloan School of Management, April 1978.

T.L. MAGNANTI and B.L. GOLDEN, "Transportation Planning: Network Models and Their Implementation," Technical Report No. 143, M.I.T. Operations Research Center, January 1978.

P.B. MIRCHANDANI and A.R. ODONI, "Locations of Medians on Stochastic Networks," Working Paper OR 065-77, M.I.T. Operations Research Center, October 1977.

S.K. MITTER and S.K. YOUNG, "Quantum Detection and Estimation Theory," Proceedings of the Fifteenth Annual Allerton Conference on Communication, Control and Computing, September 1977, pp. 62-67.

E.M. MODIANO, "Normative Models of Depletable Resources," Technical Report No. 151, M.I.T. Operations Research Center, May 1978.

P.M. MORSE, "Solution of the Retiring Search Problem," Working Paper OR 070-77, M.I.T. Operations Research Center, December 1977.

P.M. MORSE and F.F. LEIMKUHLER, "Exact Solution for the Bradford Distribution and Its Use in Modelling Informational Data," Working Paper OR 068-77, M.I.T. Operations Research Center, November 1977.

A.R. ODONI, "Recent Employment and Expenditure Trends in U.S. City Police Departments," Journal of Criminal Justice, 5, August 1977, pp. 119-147.

S. PARIENTE, "A Model for the Efficient Use of Energy Resources," Working Paper OR 067-77, M.I.T. Operations Research Center, November 1977.

S. PARIENTE, "Mathematical Programming Approaches to Modelling Technological Change, with Applications to the Energy Sector," Technical Report No. 148, M.I.T. Operations Research Center, April 1978.

S. PETERS and R.E. WELSCH, "Finding Influential Subsets of Data in Regression Models," Proceedings of the Computer Science and Statistics: Eleventh Symposium on the Interface, A.R. Gallant and T.M. Gerig (eds.), North Carolina State University, 1978, pp. 240-244.

PROFESSIONAL ACTIVITIES: Publications

L.B. SCHWARZ, S.C. GRAVES and W.H. HAUSMAN, "Scheduling Policies for Automatic Warehousing Systems: Simulation Results," Technical Report 77-4, Stanford University Department of Industrial Engineering and Engineering Management, September 1977.

J.F. SHAPIRO, "Sensitivity Analysis in Integer Programming," in Annals of Discrete Mathematics 1: Studies in Integer Programming, P.L. Hammer, E.L. Johnson, B.H. Korte and G.I. Nemhauser (eds.), North Holland Publishing Company, 1977, pp. 467-478.

J.F. SHAPIRO and A. KAZMI, "Models for Planning Investments in Electric Power and Water Supply in Saudi Arabia," in Energy Use and Management, Volume 1, R.A. Fazzolare and C.B. Smith (eds.), Pergamon Press, 1977, pp. 873-878.

J.F. SHAPIRO and D.E. WHITE, "Integration of Nonlinear Coal Supply Models and the Brookhaven Energy System Optimization Model (BESOM)," Working Paper OR 071-78, M.I.T. Operations Research Center, January 1978.

W.B. SHEPARDSON, "A Lagrangean Relaxation Algorithm for the Two Duty Period Scheduling Problem," Technical Report No. 152, M.I.T. Operations Research Center, June 1978.

D.W. TALAFUSE, "Blood Donor Attitudes and Decisions: An Exploratory Analysis," Technical Report No. 137, M.I.T. Operations Research Center, February 1978.

J.M. TIEN and R.C. LARSON, "Police Service Aides: Paraprofessionals for Police," Journal of Criminal Justice, 6, 1978, pp. 117-131.

R.E. WELSCH, "Tables for Stepwise Multiple Comparison Procedures," Working Paper 949-77, M.I.T. Sloan School of Management, 1977.

R.E. WELSCH, "Stepwise Multiple Comparison Procedures," Journal of the American Statistical Association, 72, September 1977, pp. 566-575.

R.E. WELSCH, "Nonlinear Statistical Data Analysis," Proceedings of the Computer Science and Statistics: Tenth Symposium on the Interface, D. Hogben (ed.), National Bureau of Standards, February 1978, pp. 77-86.

R.E. WELSCH, "Computing Regression Diagnostics," Proceedings of the Stanford Conference on Numerical and Statistical Computing, G. Golub and V. Klema (eds.), 1978.

T.R. WILLEMAIN, "Bayesian Analysis of Crime Rate Changes in Before-and-After Experiments," Working Paper OR 075-78, M.I.T. Operations Research Center, June 1978.

T.R. WILLEMAIN and R.C. LARSON (eds.), Emergency Medical Systems Analysis, Lexington Books, 1978.

PROFESSIONAL ACTIVITIES

B. Presentations

A.I. BARNETT, "On the Handling of Queueing Systems with Demands at Many Points," (co-authored with J. Mazzarino), Joint ORSA/TIMS National Meeting, Atlanta, Georgia, November 1977.

O. BERMAN, "Repositioning of Urban Services and Markovian Decision Processes," (co-authored with A.R. Odoni), Joint ORSA/TIMS National Meeting, Atlanta, Georgia, November 1977.

J.A. BLOOM, "Decomposition and Probabilistic Simulation in Electric Utility Planning Models," Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

A.W. DRAKE, "Public Involvement in the Whole Blood Supply," Center for Blood Research, Boston, Massachusetts, March 1978.

A.W. DRAKE, "People and Blood Donation," District 5 New England Regional Red Cross Blood Program, Bedford, Massachusetts, March 1978.

A.W. DRAKE, "Public Attitudes and Decisions with Regard to Blood Donation," Annual Meeting of the Penn-Jersey Region Red Cross Blood Program, Philadelphia, Pennsylvania, June 1978.

J. FERREIRA, JR., "Identifying Equitable Insurance Premiums for Risk Classes: An Alternative to the Classical Approach," XXIII International TIMS Meeting, Athens, Greece, July 1977.

J. FERREIRA, JR., "Equitable Pricing of Risk Classes," Decision Under Uncertainty Seminar, Harvard University, Cambridge, Massachusetts, September 1977.

J. FERREIRA, JR., "Remarks about the Equity of Risk Classification," Society of Actuaries and Casualty Actuarial Society Joint National Meeting, New York, New York, April 1978.

T.L. FRIESZ, "Search Models, Residential Mobility and Linear Programming," (co-authored with P.D. Hall), Northeast Regional Science Association Annual Conference, Baltimore, Maryland, May 1978.

T.L. FRIESZ, "Transport Project Evaluation: A Review of Multiobjective Optimization Methods," Cairo University/M.I.T. Conference on Transportation Planning Policy, Cairo, Egypt, June 1978.

S.C. GRAVES, "Multiproduct Production Cycling Problem," Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

PROFESSIONAL ACTIVITIES: Presentations

S.C. GRAVES, "Improved Scheduling for Automatic Warehousing Systems: Simulation Tests," (co-authored with L.B. Schwarz and W.H. Hausman), Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

S.C. GRAVES, "Logistic Failure vs. Mission Failure in Reliability Specification," (co-authored with J. Keilson), Department of Defense Acquisition Research Symposium, Hershey, Pennsylvania, June 1978.

A.C. HAX, "Centralized Production-Distribution System," (co-authored with N. Majluf and M. Pendrock), ORSA/TIMS Conference on Distribution Modelling, Hilton Head, South Carolina, February 1978.

A.C. HAX, "Comparative Analysis of Project Management in the Private and Public Sectors," Conference on Government Procurement Policy, George Washington University, Washington, D.C., May 1978.

A.C. HAX, "Management Science in Developing Countries - Applications and Attitudes," Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

R.C. LARSON, "Markov Models of Fixed Post Sensor AVL Systems," Joint ORSA/TIMS National Meeting, Atlanta, Georgia, November 1977.

R.C. LARSON, "OR and Municipal Services: Implementation Problems and Prospects," Joint ORSA/TIMS National Meeting, Atlanta, Georgia, November 1977.

R.C. LARSON, "Structural System Models for Locational Decisions: An Example Using the Hypercube Queueing Model," First International Symposium on Locational Theory, Banff, Alberta, Canada, April 1978.

R.C. LARSON, "Structural System Models for Locational Decisions: An Example Using the Hypercube Queueing Model," 1978 Meeting of the IFORS, Toronto, Ontario, Canada, June 1978.

J.D.C. LITTLE, "Supply Modeling for Urban Traffic Management," (co-authored with N.H. Gartner and S.B. Gershwin), International Symposium on Travel Supply Models, Montreal, Quebec, Canada, November 1977.

J.D.C. LITTLE, "Computer-Assisted Traffic Engineering Applied to Energy Consumption on Roadway Networks," (co-authored with S.B. Gershwin and N.H. Gartner), Lawrence Symposium on Decision Sciences, Berkeley, California, October 1977.

J.D.C. LITTLE, "Optimization of Large Traffic Systems," (co-authored with S.B. Gershwin, P. Ross and N.H. Gartner), 57th Annual Meeting, Transportation Research Board, Washington, D.C., January 1978.

PROFESSIONAL ACTIVITIES: Presentations

T.L. MAGNANTI, "Accelerating Linear Approximation Techniques for Network Optimization," XXIII International TIMS Meeting, Athens, Greece, 1977.

T.L. MAGNANTI, "Solving Network Design Problems: A Status Report," IEEE Workshop on Network Design and Reliability, Atlanta, Georgia, November 1977.

T.L. MAGNANTI, "Modeling of Rail Networks," (co-authored with A.A. Assad), Joint ORSA/TIMS National Meeting, Atlanta, Georgia, November 1977.

T.L. MAGNANTI, "Supply Modeling of Rail Networks," International Symposium on Traffic Supply Models, Montreal, Quebec, Canada, November 1977.

T.L. MAGNANTI, "Static Models: Road, Rail and Air," IEEE Workshop on Transportation and Communication Networks, New York, New York, May 1978.

T.L. MAGNANTI, "Network Analysis of Transportation Systems," Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

S.K. MITTER, "The Mathematics of System Theory and Quantum Communications," Department of Electrical Engineering, University of Maryland, College Park, Maryland, December 1977 - March 1978.

S.K. MITTER, "Duality for Linear Input-Output Maps," Electrical Engineering Department, Stanford University, Stanford, California, March 1978.

S.K. MITTER, "On the Innovations Conjecture," Electrical Engineering Department, Stanford University, Stanford, California, March 1978.

A.R. ODONI, "Evaluation of Airport Planning Models," Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

A.R. ODONI, "The Aircraft Sequencing Problem," (co-authored with H. Psaraftis), Optimization Days 1978, Montreal, Quebec, Canada, May 1978.

J.F. SHAPIRO, "Mixed Integer Programming Investment Planning Models," Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

R.E. WELSCH, "Using Sensitivity Analysis to Detect Leverage Points in Data," XXIII International TIMS Meeting, Athens, Greece, July 1977.

R.E. WELSCH, "A Comparison of Regression Diagnostics," ASA Annual Meeting, Chicago, Illinois, August 1977.

PROFESSIONAL ACTIVITIES: Presentations

R.E. WELSCH, "Influential Data," Bell Telephone Laboratories, Holmdel, New Jersey, January 1978.

R.E. WELSCH, "Finding Influential Subsets of Data in Regression Models," North Carolina State University, Raleigh, North Carolina, March 1978.

R.E. WELSCH, "Bounded Influence Estimation," IMS Regional Meeting, University of Kentucky, Lexington, Kentucky, March 1978.

R.E. WELSCH, "Influential Subsets of Data in Regression," Statistics Seminar, University of Minnesota, Minneapolis, Minnesota, March 1978.

V. ADMINISTRATION

A. Personnel

Academic Staff

R.C. LARSON, Co-Director
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A.C. HAX
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D.H. MARKS
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S.K. MITTER
Professor of Electrical Engineering

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Professor of Physics, Emeritus

A.R. ODONI
Associate Professor of Aeronautics and Astronautics

R.E. WELSCH
Associate Professor of Operations Research and Management

T.R. WILLEMAIN
Associate Professor of Urban Studies

Research Staff

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R.W. BROWN
V. CHANDRU
S.S. CHIU
C. COZZI
D.P. ELLIOTT
S.E. ERIKSEN
W.G. GOLUSH
H. GUILLAMON-DUCH
J.H. HAMMOND
S. KALISH
E.H. KAPLAN
M.D. KELSON
B.W. LAMAR
V.O.K. LI
Z.A. LIVNE
J.R. LUQUE
E.M. MODIANO
M.C.M. MUI
L.K. OLESEN

ADMINISTRATION: Personnel

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F.H. PICKEL
E.J. ROTH
G. SADIQ
D. SARKAR
E.L. SCHWARTZ
M. SEPEHRI
M. SHAHJAHAN
W.B. SHEPARDSON
Y. SUGITA
J.S. VALOR
P.A. VILLELA
D.P. WEILMUENSTER
H.H. YANASSE

Administrative and Clerical

C.S. GOODRICH
Administrative Assistant

D.J. GREEN
Secretary

M.J. HEIGHAM
Administrative Assistant

K. SUMERA
Secretary

B. Research Support

The operations research work reported in Section II has been supported in various ways--some by the Center directly and some by centers, laboratories and departments within M.I.T. Below are the individuals whose work was directly supported, in whole or in part, by O.R. Center contracts and grants during 1977-78.

A.A. ASSAD	S.C. GRAVES	R.E. MARSTEN
V.M. BIER	E. HAAS	C.F. MATTINGLY
G.R. BITRAN	A.C. HAX	L. OLESEN
J.A. BLOOM	E.H. KAPLAN	S. PARIENTE
D.I. CANDEA	M.D. KELSON	M.E. PENDROCK
C.L. CARTER	W. KRASKER	D. SARKAR
V. CHANDRU	B.W. LAMAR	J.F. SHAPIRO
J.S. D'AVERSA	R.C. LARSON	P.A. VILLELA
D.P. ELLIOTT	R. LELAND	R.E. WELSCH
R.T. FISHER	D.S. LINTZ	D.E. WHITE
J.J. GOLOVIN	T.L. MAGNANTI	T.R. WILLEMAIN

O.R. Center Contracts and Grants, July 1, 1977 - June 30, 1978

ARMY RESEARCH OFFICE
"Basic Studies in Combinatorial and Nondifferentiable Optimization"

DEPARTMENT OF TRANSPORTATION
"Transportation Network Analysis and Decomposition Techniques"

ENERGY RESEARCH AND DEVELOPMENT ADMINISTRATION
"Extensions and Analysis of the Brookhaven Dynamic System Optimization Model"

LAW ENFORCEMENT ASSISTANCE ADMINISTRATION
"An Empirical Study of Methods Used in Criminal Justice Evaluations"

LAW ENFORCEMENT ASSISTANCE ADMINISTRATION
"On Another Approach to Criminal Justice Statistical Analysis"

MASSACHUSETTS AUTOMOBILE RATING AND ACCIDENT PREVENTION BUREAU
"Evaluating the Consumer's Interest in Merit Rating Plans"

NATIONAL SCIENCE FOUNDATION
"Experimental and Theoretical Investigations into Integer Programming Dual Methods"

NATIONAL SCIENCE FOUNDATION
"Software for Nonlinear Optimization: Nonlinear Robust Regression"

ADMINISTRATION: Research Support

OFFICE OF NAVAL RESEARCH
"Multilevel Logistics Organization Models"

PUBLIC HEALTH SERVICE
"Blood Donor Motivation and Recruitment"

INDEX TO AUTHORS OF REPORTS IN SECTION II


EN
DAT
FILM

R.C. LARSON and E.A. FRANCK, "Evaluating Dispatching Consequences of Automatic Vehicle Location in Emergency Services," Journal of Computers and Operations Research, 5, 1978, pp. 11-30.

J.D.C. LITTLE, "Maximal Bandwidth for Arterial Traffic Signals: Theory and Interactive Computation," Working Paper 970-78, M.I.T. Sloan School of Management, September 1977.

S. PARIENTE, "A Model for the Efficient Use of Energy," Working Paper OR 067-77, M.I.T. Operations Research Center, November 1977.

S. PARIENTE, "Mathematical Programming Approaches to Modelling Technological Change, with Applications to the Energy Sector," Technical Report No. 148, M.I.T. Operations Research Center, April 1978.

S. PETERS and R.E. WELSCH, "Finding Influential Subsets of Data in Regression Models," Proceedings of the Computer Science and Statistics: Eleventh Symposium on the Interface, A.R. Gallant and T.M. Gerig (eds.), North Carolina State University, 1978, pp. 240-244.

Stanford Conference on Numerical and Statistical Computing, G. Golub and V. Klema (eds.), 1978.

T.R. WILLEMAIN, "Bayesian Analysis of Crime Rate Changes in Before-and-After Experiments," Working Paper OR 075-78, M.I.T. Operations Research Center, June 1978.

T.R. WILLEMAIN and R.C. LARSON (eds.), Emergency Medical Systems Analysis, Lexington Books, 1978.

T.L. FRIESZ, "Transport Project Evaluation: A Review of Multiobjective Optimization Methods," Cairo University/M.I.T. Conference on Transportation Planning Policy, Cairo, Egypt, June 1978.

S.C. GRAVES, "Multiproduct Production Cycling Problem," Joint ORSA/TIMS National Meeting, New York, New York, May 1978.

California, October 1977.

J.D.C. LITTLE, "Optimization of Large Traffic Systems," (co-authored with S.B. Gershwin, P. Ross and N.H. Gartner), 57th Annual Meeting, Transportation Research Board, Washington, D.C., January 1978.

R.E. WELSCH, "Using Sensitivity Analysis to Detect Leverage Points in Data," XXIII International TIMS Meeting, Athens, Greece, July 1977.

R.E. WELSCH, "A Comparison of Regression Diagnostics," ASA Annual Meeting, Chicago, Illinois, August 1977.

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